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FIELD STUDIES ON THE EFFECT OF DDT ON AQUATIC INSECTS[1/]

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During 1945 a number of streams and ponds were given experimental treatments with DDT to obtain data on its effect on their macroscopic invertebrate faunas. In studying a given body of water, the procedure was to obtain pretreatment information on the species present and the population density of each. The treatment was applied shortly after this estimate was completed. The species present and the population density of each were checked after treatment by the same methods, and the differences, when not paralleled in similar untreated habitats, construed to be due to DDT. The occurrence of dead or dying specimens after the treatment was considered evidence that DDT was responsible for depletion or elimination of a species. Population surveys at intervals after the treatment gave information on how long DDT was present in lethal amounts, the rate of repopulation, and additional data on the species eliminated or reduced.

Studies on Aquatic Invertebrates in Streams

Parts of three trout streams near Scranton, Pa., and a section of the Patuxent River near Bowie, Md., were treated by airplane with an oil solution of DDT. The dosage ranged from 1 to 5 pounds of DDT per acre, but the amount actually deposited on the water surface was estimated to be one-fifth to one-third of that applied. Each of these treatments is discussed as a separate experiment.

[1/]Acknowledgment is made to the Division of Gypsy and Browntail Moths Control, especially to J. M. Corliss, for supervising the spraying of the streams; to the Division of Insecticide Investigations for the DDT analyses; to the Fish and Wildlife Service of the U. S. Department of the Interior, for data on the rate of flow of Ash Creek and on the amount of DDT deposited on the Patuxent River; and particularly to the following specialists for assistance with the determination of specimens: Jay Traver, Massachusetts State College (Ephemerida); J. P. E. Morrison, Smithsonian Institution (Mollusca).

Collection methods.--Quantitative data on the bottom faunas were secured with a stream square-foot sampler designed by A. D. Hess.[2/] This sampler consists of a cylinder 2 feet high, open at the ends, of a diameter (13.6 inches) to cover 1 square foot of stream bottom. The side of the cylinder placed upstream is covered with 16-mesh screening, allowing the current easy access. The downstream side is covered with heavy canvas, which directs the current into a long conical bag of scrim netting sewed to an opening in the canvas. Stones and vegetation in the enclosed square foot are washed by hand as clean as possible of organisms, and the remaining gravel is stirred vigorously with a stick. Once detached, the organisms are washed into the bag by the current, and at the completion of the collection the bag is emptied into white enameled pans and the catch separated from the debris with pipettes and forceps. Figure 1 shows the apparatus in use.

To obtain accurate results the sampler should be used by a person knowing the habits and distribution of the organisms being sampled, and the work must be done under favorable conditions. It is important to have the lower edge of the sampler fit the stream bottom tightly. Large stones frequently prevent this and make accurate sampling impossible, as many of the organisms are washed through the cracks around them. Under good conditions probably about 80 percent of the larger specimens present are collected. In the present study collections were made only in riffles. Slower stretches contain fewer specimens and are more difficult to sample.

A valuable supplement to the square-foot sampler is a screen collector. This consists of a piece of 16-mesh wire screening about 3 feet wide and 2 feet high, the ends of which are tacked to wooden stakes that project upwards as handles. In use, the screen is placed across the current and held in place by means of the wooden handles. With one foot or a stick the operator can then stir the bottom stones and gravel upstream. The current washes the dislodged organisms against the screen, which when lifted from the water brings them with it. This is a very simple and effective device, but it is not practical for obtaining quantitative data because the size of the area collected is difficult to control.

[2/] Hess, A. D. New limnological sampling equipment. Limnological Soc. Amer. Spec. Pub. 6: 2-3, illus. 1941.

The ravine brook.--The stream referred to here as the ravine brook is located in Spring Brook township, near Scranton, Pa., about 4 miles southeast of the town of Moosic. It empties into Spring Brook a few hundred feet below the mouth of Green Run. It is about 0.4 mile long, arises in and flows through a broad ravine on the side of a small mountain, and consists of alternating drops, pools, and short riffles. In the drier part of the summer all but its lower few hundred feet dries to an underground trickle. At other times it is about 2 feet wide and 2 to 4 inches deep. In 1945, a wet summer, it was about this size all summer except for a few days late in July when most of the stream went dry. Because of the temporary nature of the stream, its fauna is rather scanty, consisting of species able to survive during dry periods in isolated pools or in the dampness or percolating water of leaf drifts and gravel.

From May 21 to June 1 all but the lower 800 feet of the stream and its watershed was sprayed by airplane at the rate of 4 to 5 pounds of DDT per acre. The area was covered in sections as weather permitted airplane operation. The formula, per gallon of spray, was 1 pound of DDT, 1 quart of xylene, and 2.82 quarts of horticultural spray oil. The course of this stream was through moderately thick forest the foliage of which caught much of the spray, so that the DDT reaching the surface of the stream averaged probably less than a pound per acre, with local variations. The actual deposit was not measured. An unknown quantity of spray drifted onto the lower 800 feet of the stream, which was intended to be untreated.

Within an hour after the spray was applied, nymphs and larvae of Ameletus, Leuctra, Diploperla, Pycnopsyche, and others could be seen swimming and crawling in the same erratic and awkwardly ineffective manner that characterizes terrestrial insects affected by DDT. Collections in the stream 10 days later showed decaying remains of large numbers of various aquatic insects and of crayfish in the stream bottom, most of them in the bottoms of the small pools to which they had been carried by the current.

Pretreatment quantitative collections of the bottom fauna were taken with the stream square-foot sampler on May 5 and 17. The samples were taken at two stations near the lower edge of the area to be sprayed with DDT and at one station 750 feet below it. Ordinarily two square-foot samples were taken at each station on each date. On June 6 and 29, 5 and 28 days after treatment, the collection stations were visited again and square-foot samples taken, two at each station on June 6 and three at each station on June 29. On June 29 and August 27 the screen collector was used five times at each station in an effort to collect scarce species

missed in the square-foot samples.

The forms taken in each square-foot sample are listed for each station in table 1.

The table shows that at two stations in the sprayed section of the stream all invertebrates except worms and some of the more resistant insect species were apparently exterminated. Most of the insect survivors were those protected in leaf drifts. The reduction in the number of invertebrates present at the upper station was 92 percent and at the middle station 87 percent. At the third, or lower, station, about 750 feet below the sprayed area, the fauna was subjected to spray drift and to DDT carried down by the stream. Between the sprayed area and this station, however, there is considerable seepage through leaf drifts and gravel, which probably removed much of the DDT. A few of the more susceptible species seem to have been exterminated here, but most were reduced only moderately or not at all. Because these few susceptible species made up a large portion of the pretreatment population, their elimination resulted in an over-all reduction of 80 percent.

The table includes an estimate as to whether a given species was exterminated, reduced, or not affected by the DDT treatment. This estimate takes into account the figures in the table and in addition the information from the screen collections and whatever other knowledge was available about the habits of the species and their susceptibility to DDT. In the case of many species too few specimens were found to warrant a conclusion.

Ash Creek.--Ash Creek is a clean, cold stream located in Clifton township, Pa. It empties into the Lehigh River near the town of Clifton. Ash Creek arises in a dense rhododendron swamp and flows through an open marshy area immediately above the section treated. The upper mile of the treated section of the stream averages about 10 feet wide and 10 inches deep, with a canopy mostly of large overhanging trees. The lower 2 miles is increasingly more open, except for occasional areas overgrown by alder, with alternating riffles and pools. Toward the mouth there are deep slow stretches where the stream is 12 to 18 feet wide. At one collection station the rate of flow was about 4,300 gallons per minute. There is an abundance of aquatic vegetation, with Fontinalis on many of the stones and in summer a heavy growth of Ranunculus trichophyllus Choix and many patches of Callitriche heterophylla Pursh. The clean water, abundance of aquatic vegetation, and swampy origin make Ash Creek very rich in insect life.

On August 9 the lower 3 miles of Ash Creek was sprayed with

DDT by airplane at the rate of 1 pound in a gallon of solution per acre. The formula per gallon of spray was 1 pound of DDT to 1 quart of xylene and 3 quarts of kerosene. The method of spraying was to fly a single swath the length of the stream and then to cover with a second swath the bends of the stream which could not be covered with the first.

To estimate the actual amount of DDT deposited on the stream, 27 filter-paper disks 13 inches in diameter were laid out on supports in the center of the stream, along the banks, and as far as 100 feet from the stream center. The deposits on these disks were analyzed for DDT and found to range from 0.009 to 1.40, and average 0.23 pounds per acre. The data obtained were inconclusive, but indicate that only a fraction of the DDT released, possibly a fourth, actually reached the stream.

Pretreatment collections of the bottom fauna were taken with the stream square-foot sampler on July 14 and 30 and on August 8 (1 day before treatment). The collections were made at stations 200 feet, 1 mile, and 1.5 miles above the mouth of the stream. Ordinarily, two square-foot samples of the bottom fauna were taken at each station on each date.

On August 23 (14 days after treatment) the same three stations were visited again and two square-foot collections made at each. The collecting screen was used four times at each station to determine the presence or absence of species too scarce to be collected with the square-foot sampler. To find out whether or not the relative scarcity of certain species after the spraying could be explained as a result of their normal life cycles, a square-foot collection was made in Silver Creek, a smaller stream about half a mile away having a fauna and ecology similar to those of Ash Creek.

Table 2 gives the contents of the square-foot samples in Ash Creek on July 14 (before treatment) and on August 23 (after treatment) and of the check sample taken in Silver Creek on August 23. The pretreatment collections of July 30 and August 8 are not listed in the table. They were made under the difficult conditions of very high water and are therefore scantier than those of July 14. However, a study of their contents indicates that there was no material change in the abundance of the various insect species between July 14 and August 8, 1 day before the treatment.

According to table 2 there was a 48-percent reduction of the invertebrates at the upper station, a 90-percent reduction at the middle station, and a 78-percent reduction at the lower station. The last figure is somewhat misleading because much of the

survival is represented by a single species, Ephemerella rotunda Morg. The individuals of this species taken after the spraying were all very small, and it is probable that many of them did not hatch until after the spray was applied. If this species is eliminated from consideration, the reduction at the lower station was 90 percent. The relatively small reduction at the upper station is probably due to the fact that the stream section above it is largely covered by a forest canopy, and much of the DDT that did reach its surface was probably lost in the swamps, trash, vegetation, seepage areas, and short underground stretches that characterize this section of the stream. Below the upper station the stream is relatively uninterrupted. Moreover, the organisms at the lower stations were subjected to more run-off of treated water from upstream.

Data presented in table 2, supplemented by data from the square-foot collections of July 30 and August 8 and the screen collections of August 23, show rather conclusively the degree to which the commoner species survived the spray. An estimate of the survival of most species is given in the table.

Bowback Creek.--Bowback Creek is in Spring Brook township, near Scranton, Pa. It enters Rattlesnake Creek about 2 miles above Nesbitt Reservoir. It bears no name on the maps known to us. We have accepted the name used by a local farmer. It rises in and flows for about half a mile through upland swampy areas. The section studied is below this, where the stream flows through a narrow valley. Here it is about 6 feet wide and 6 inches deep. Its bottom is of slab rubble underlain by gravel, and it drops steeply over frequent or almost continuous riffles. Part of it is open to the sun and part covered by trees and bushes. Its fauna of aquatic insects is abundant and varied.

On June 9 a 350-acre tract including about 60 percent of the watershed of Bowback Creek was sprayed by airplane with DDT at the rate of 1 pound per acre. The formula per gallon of spray was 1 pound of DDT to 1 quart of xylene and 2.82 quarts of horticultural spray oil. No measurement of the actual deposit was taken. Through a misunderstanding the pilot tried to avoid spraying the stream. Nevertheless, the lower 1,000 feet (more or less) in the treated area was covered by the spray.

Pretreatment collections were made with the square-foot stream sampler at three stations in the area to be treated--about 100 feet, 350 feet, and 800 feet above the lower boundary. To see whether DDT would be carried down by the stream in a quantity sufficient to kill aquatic insects, pretreatment collections were made on the stream about a quarter mile below the sprayed area

(just above its mouth) and in Rattlesnake Creek about 800 feet below the entry of Bowback Creek. Two square-foot samples of the bottom fauna were taken at each of these five stations on May 3-4 and on June 6-7. Posttreatment collections were made on June 28-29, on July 25-26, and on August 28. The June and July collections were made with the square-foot sampler, two samples at each station, supplemented by screen collections at each of the three stations within the sprayed area. The August collecting was done with the screen collector only.

Since the station in Bowback a quarter mile below the treated area and that in Rattlesnake Creek below the mouth of Bowback both showed no change in fauna attributable to DDT, they made satisfactory check stations. Table 3 gives the contents of each of the square-foot samples. Material from the screen collections is not included. Information on 27 forms on which the results seemed significant are given, though 127 forms were studied.

Collection data for June 28 indicate reductions of 71, 87, and 63 percent from the June 7 population counts at the upper, middle, and lower stations in the sprayed area. At the upper and lower stations Cricotopus larvae made up a large portion of the posttreatment population. Since these larvae were probably from eggs hatching after the spraying, the species may with some justice be eliminated from the data as not a true survivor, giving a reduction of 76, 89, and 85 percent at the respective stations. Collection data for July 25 indicate reductions of 51, 91, and 87 percent from the numbers at the three stations on June 7, Cricotopus not being present on July 25.

Table 3 shows that at the Bowback Creek and Rattlesnake Creek check stations there were natural reductions excluding Cricotopus of 30 and 32 percent between June 7 and June 28 and a reduction of 89 and 44 percent between June 7 and July 25. This was due mainly to the emergence of adults from maturing nymphs and larvae. Even susceptible Ephemerida were present in numbers at the two check stations after treatment, an indication that little, if any, of the reduction was due to DDT carried down from the treated section of Bowback Creek. Water in the Bowback check station was very low on July 25, which is the probable reason for the small number of specimens collected then. Thus, the July 25 data from the Bowback check station were not used in computing the reduction due to DDT.

To take into account natural seasonal reduction as indicated by the check stations, one uses the formula $(X-Y)100/X$ = the percent reduction due to DDT alone, where X is the percent survival at the check stations and Y is the percent survival at the

treated stations. Using this formula one arrives at a June 28 reduction due to DDT of 65 percent at the upper station, 84 percent at the middle station, and 78 percent at the lower station. On July 25 the reductions at the three stations were 13, 84, and 77 percent. These percentages are probably nearer to the true effect of the treatment.

In table 3 an estimate is given of the effect of DDT on each species at the middle and lower stations in the sprayed area. This estimate takes into consideration the screen collections as well as the square-foot collections, also what information we have about the biologies of the various species. When only a few specimens of a species were taken, several species were grouped, as "Other Ephemerida."

Patuxent River.--The Patuxent River flows through the Patuxent Research Refuge, near Bowie, Md. Here the river is flat and slow-flowing, about 60 feet wide, and with an average depth of about 20 inches. It carries a heavy load of silt and some sewage pollution. Riffles are rare, and aquatic vegetation is scanty. These unfavorable factors result in a poor fauna of aquatic insects. Mollusks are rather abundant.

A 117-acre tract on the Patuxent Research Refuge, with a 0.9-mile stretch of the Patuxent River flowing through it, was sprayed with DDT by airplane at the rate of 2 pounds per acre on June 5. The formula per gallon was 1 pound of DDT, 1 quart of xylene, and 2.65 quarts of fuel oil No. 2. Eighteen petri plates 4 inches in diameter were exposed to the spray deposit along the river bank. These plates received an average of 0.6 pound of DDT per acre (range 0.004 to 1.44 lb.). Since some of them were under overhanging foliage, the average deposit on the river was probably a little higher.

On June 1 pretreatment quantitative collections of the bottom fauna were made with the square-foot sampler and with the screen collector at three likely points on the river. The only collecting station that yielded enough aquatic insects to warrant further study was at a riffle at the lower end of the area to be sprayed. Three square-foot samples and a number of screen collections were taken here. On June 20, 15 days after the spray, this station was visited again and a like number of square-foot samples and screen collections were made.

These collections showed no reduction in the fauna which could be attributed to DDT. Aquatic snails (Helisoma anceps (Menke), Goniobasis virginica (Gmel.), Clappia virginica (Wlk.), Physella heterostropha (Say), and Fossaria humilis (Say)) and three other

less common species and a small clam (Sphaerium) were as abundant as before. Among the aquatic insects, nymphs of Perlesta placida (Hag.) were much less numerous than before the spray, but the reduction seemed to be due to the emergence of adults, as on June 1 most of the nymphs were mature. Larvae of Dineutes and Hydrobaeninae (Tendipedidae) and nymphs of Macromia were about as common after the spraying as before. Too few of other forms were taken to warrant drawing conclusions about them.

Studies on Aquatic Invertebrates in Ponds

Description of ponds.--In late March and early April of 1945 seven small ponds on the Patuxent Research Refuge near Bowie, Md., and two larger ponds near Beltsville, Md., were studied to ascertain the effects of DDT on the kinds of macroscopic invertebrates inhabiting them. The size and depth of each pond and the rate and kind of spray treatment are summarized in table 4. Ponds 1 to 7, on the Refuge, are part of a series of rectangular artificial experimental ponds with practically vertical sides, dug during 1937 and 1938 in clayey terrace land. The deeper ones have emergent grasses, sedges, Juncus, and other plants around their margins, and the shallower ones also have emergent vegetation in the central part, with a resulting mat of decaying vegetable debris over the bottom. Ponds 4 and 5 are relatively barren of vegetation. When rains are insufficient, these ponds are filled with water piped in. Each one has an overflow drain. Ponds 8 and 9 are on the lands of the Agricultural Research Center at Beltsville, Md. They are in abandoned mine pits, have steep sides (with a few shallow coves), and a marginal fringe of Sphagnum, emergent vegetation, and Nuphar. Their bottoms are of fine soft muck overlain with dead leaves and the decaying remains of aquatic plants. Pond 8 is more open to the sun than pond 9 and has more aquatic vegetation and a more abundant fauna. It has an outlet, a small slow streamlet; pond 9 has no outlet.

Treatments.--Ponds 3 to 8 were treated with a DDT-oil solution (DDT 1 lb., xylene 1 qt., and fuel oil No. 2 to make a gallon) at the rates of 1, 3, and 5 pounds of DDT per acre of water surface (table 4). To differentiate between the effects of DDT and of its solvent, ponds 1 and 2 were treated with the solvent used for the DDT (xylene 1 qt. and fuel oil No. 2 3 qt.) at the rate that would be used to apply 5 pounds of DDT per acre. Pond 9 was treated with DDT in an emulsion (DDT 1 lb., xylene 1 qt., Igepal (alkyl aryl polyglycol ether) 20 ml., and water to make 1 gallon) at the rate of 5 pounds of DDT per acre. Ponds 1 to 7 were sprayed on April 11, pond 8 on April 2, and pond 9 on March 28.

Sprays for ponds 1 to 7 were dispensed from a small hand

atomizer, which gave a continuous fine spray. Air currents were taken into consideration during the applications, and the operator frequently moved from one side of a pond to another, depending upon the direction of the wind, in order to deposit a maximum quantity of the spray uniformly over the water surface. A small amount of the spray, however, was lost as a result of drift. The oil droplets reaching the water coalesced quickly and formed a continuous film over each pond. A compressed-air sprayer equipped with a nozzle adjusted to give a coarse spray was used on ponds 8 and 9, which also became covered with a continuous oil film. On pond 8 rain fell during and after the application, which may have helped mix the spray with the water.

Five-gallon subsurface water samples taken 8 days after treatment in pond 5 showed a presence of 0.017 p.p.m. of DDT, or 0.076 pound of DDT per acre, and similar samples taken from pond 9 after 9 days showed 0.021 p.p.m. of DDT, or 0.29 pound per acre. Two other samples from the same ponds, taken to include 12 square feet of undisturbed surface film with each sample, gave DDT analyses about 40 percent higher than the subsurface samples, indicating a concentration at the surface film. All DDT analyses were made by a colorimetric method.

Collection methods.--Efforts were made to get a reasonably accurate idea of the species present in each pond and their abundance before and at intervals after the treatments, and to make observations and counts on dead and dying insects after the treatments. Population surveys were made by several methods. The surface insects, such as gerrids and gyrinids, were counted or their numbers estimated, and the free-living and bottom forms were collected by dip nets. The dip nets were used in a random way for general reconnaissance and with a certain number of sweeps of a certain length for quantitative data. The observations on ponds 1 to 7 were made on April 10, 11, 16, 19 and June 19, on ponds 8 and 9 on April 2, 3, 6, 16 and June 21, and on pond 8 also on March 29.

An Ekman dredge was used to obtain data on the small forms of the bottom. This type of dredge takes up the bottom mud and debris of an area 6 inches square to a depth of about 2 inches. Each haul is washed in a close-meshed bag to rid it of mud and the residue washed into white-bottomed pans, where the organisms can be picked out with forceps or pipette. If the work is done carefully, the resulting sample is an accurate measure of the fauna of one-fourth square foot of the bottom. Tediousness of handling the material limits the number of samples that may be taken with an Ekman dredge. Two dredge samples from ponds 1 to 7 were taken on April 10 to 19, and one from each on June 19.

Results.-- In ponds 1 and 2, which were treated only with the solvent used for the DDT in other experiments, all surface and surface-breathing insects were dead within a day. They did not die so quickly as in the DDT-treated ponds, but the extermination was complete. Repopulation was under way 5 days after treatment, sooner than in the ponds treated with DDT. Subsurface and bottom forms showed no harmful effects from the spray.

In ponds 3 to 7, which were treated with DDT at 1 to 5 pounds per acre, most of the surface and surface-breathing insects were dead in a few hours and all within a day, with the exception of Belostomatidae. There had been a moderately heavy population, including Dineutes, Gyrinus, hydrophilids, Gerris, Hydrometra, Mesovelia, Notonecta, and corixids. Repopulation by migrants was searched for 5 to 8 days after treatment. Except for a few belostomatids, which appeared to be survivors, three specimens of Gerris marginatus Say on pond 4, 8 days after the application, is all that was found. Eight days after the application dip-net collections of the subsurface insects in pond 4 showed a reduction of the Enallagma nymphs and an apparent extermination of Callibaetis; in pond 7 an apparent extermination of the formerly abundant Enallagma nymphs; and in ponds 4, 5, and 7 no reduction in the population of Libellula lydia Drury, a resistant species. No survivors were found in ponds 3 or 6, but their pretreatment faunas were relatively scanty. The bottom organisms collected by the Ekman dredge showed some (perhaps not significant) reduction of certain species of tendipedid larvae in pond 3, possibly some reduction in ponds 4 and 5, and apparently no reduction in ponds 6 or 7. There was apparently no reduction of larvae of other Tendipedidae, Heleidae, Empididae, Chrysops or of small annelid worms (Naididae and Tubificidae).

On June 9, 59 days after treatment, all these ponds had an apparently normal fauna, showing no obvious effects of a DDT treatment. The species and age groups present were largely different from those found in April. Adults of aquatic Hemiptera and large nymphs of dragonflies which were characteristic of the April faunas had been largely replaced by young nymphs. Small bottom-living species were scarce in all ponds, including those treated with the solvents alone.

Pond 8, which was treated with DDT at 1 pound per acre, contained large numbers of many species of aquatic insects. Most of the surface and surface-breathing species were dead within a day after the treatment. Of the subsurface forms, Odonata nymphs, Callibaetis, and Chaoborus were reduced but still alive in numbers a day later. Four days after treatment Callibaetis and Chaoborus had been exterminated and Odonata nymphs were still further reduced. Fourteen days afterwards the reduction had reached its probable maximum, when all but the resistant species

of Odonata were at less than 1 percent of their former abundance. Another common subsurface species, Pelocoris femorata, was not affected by the treatment. The first evidence of repopulation was also found 14 days after treatment, when adults of Gerris and Dineutes and freshly hatched nymphs of Notonecta were present in small numbers. By June 21, 80 days after treatment, the pond population appeared to have regained its normal variety and abundance.

On pond 9, which was treated with a DDT emulsion at the rate of 5 pounds of DDT per acre, no pretreatment studies were made, but collections of dead specimens 1 and 6 days afterwards showed that its population of aquatic insects had been abundant and relatively varied. At the latter time the only live surface or surface-breathing insects were three adults of Gerris marginatus. Subsurface insects were represented by little more than Odonata nymphs. These declined in numbers until 19 days after treatment, when only Chrysops larvae and two species of Odonata nymphs could be found, and these in small numbers. Repopulation was slow. Until 19 days after treatment the only surface insects seen were two or three adults of Gerris marginatus at a time, one of which, 9 days after treatment, was apparently affected by DDT. Adults of Dineutes and Gerris were present 48 days after spraying. Eighty-four days after treatment various surface and surface-breathing insects were present in small numbers. An untreated pond nearby then contained the same species in very large numbers. At this time subsurface insects had increased only a little above their low point of 19 days after the application.

Annotated List of the Pond Species Observed

The following list indicates the species on which observations were made and our opinion on the effect of the DDT applications on particular species. Only those recorded as common or abundant afforded enough data for drawing definite conclusions, but the others are included. After each species are the ponds, listed by number, from which it was recorded and a symbol for its abundance in each. The symbols used for abundance are a, abundant; c, common; f, frequent; and r, rare. These refer to abundance as obtained by the methods employed, and for some species may have little relation to the actual abundance. It should be kept in mind that ponds 1 and 2 were sprayed with the solvent alone, not with DDT.

ANNELIDA

Tubifex?. 2(c). Not affected.

Limnodrilus. 1(a), 2(f), 3(a), 4(c), 5(r), 9(c). Not affected.

Placobdella parasitica (Say). 8(f), 9(r). Not affected.

CRUSTACEA

Daphnia. 8(c). Not affected. Increased after treatment.

Cyclops. 8(c), 9(c). Not affected. Appeared to increase after the treatments.

Asellus sp. 3(r). Not collected after the treatment.

Cambarus sp. A few dead specimens found in the Patuxent ponds after treatment.

COLLEMBOLA

Podura aquatica L. 1(c), 2(a), 3(c), 4(c), 5(c), 6(a), 7(f), 8(a), 9(c). Specimens on the surface of the ponds were exterminated within a day, but on ponds 1 to 6 the species was back in numbers 5 days after treatment. Pond 7 had Podura on its surface again 8 days after treatment. This species was on pond 8, 1 day after treatment and on pond 9, 6 days after. The species apparently can repopulate a pond surface from its margins as soon as the oil film has left.

EPHEMERIDA

Callibaetis. 4(c), 8(c). Exterminated in both ponds. In pond 8 many specimens were alive the day after treatment, but none were alive 5 days after.

Caenis. 1(c). Not collected after treatment.

ODONATA

Lestes. 8(a), 9(a?). Almost exterminated in both ponds. In pond 8, this species was abundant 1 day after treatment but less than 20 percent were alive 4 days later, and only about 1 percent 14 days afterwards. In pond 9 they were found alive in small numbers until 19 days after treatment, but the pre-treatment abundance is unknown.

Argia sp. 8(f). Five specimens were taken 14 days after treatment, none earlier. Presumably the species had until then been hibernating in the mud.

Nehallenia. 1 (r), 8 (r). Not affected in pond 1. One specimen taken in pond 8, 14 days after treatment.

Chromagrion sp. 9 (r). One specimen taken 8 days after treatment.

Enallagma sp. A. 1 (r), 2 (r), 4 (c), 7 (a), 8 (a). Probably not affected in ponds 1 or 2, though not collected in pond 1 after treatment. In pond 4 reduced to perhaps 30 percent 8 days after treatment. In pond 7 apparently exterminated. In pond 8 about 20 percent were alive 1 day after treatment, 5 percent 4 days after, and less than 1 percent 14 days after treatment.

Enallagma sp. B. 4 (r), 7 (r). In pond 4 one specimen collected 8 days after treatment. In pond 7 one collected before and none after treatment.

Ischnura verticalis (Say). Not found in the ponds before treatment, but on June 19 it was abundant and a dominant form in ponds 1 to 7.

Anax junius (Dru.). 8 (c). Present in numbers until at least 14 days after treatment.

Aeshna. 8 (c), 9 (c). Apparently not affected in pond 8. In pond 9 one live nymph taken 6 days after treatment, two dead nymphs taken 9 days after treatment, and none later.

Celithemis. 1 (r), 3 (r), 8 (r). One nymph each taken in ponds 1 and 3, 8 days after treatment, and one in pond 8, 4 days after.

Libellula lydia Dru. 3 (r), 4 (f), 5 (c), 7 (f), 9 (r). Apparently not affected in any of the ponds except possibly in pond 9. Here one nymph was collected 6 days after treatment, none later.

Libellula pulchella Dru. 8 (r), 9 (r). One taken in pond 8, 14 days after treatment and one in pond 9, 6 days after.

Libellula spp. 4 (r), 6 (f), 8 (c), 9 (c). Not reduced in any of the ponds.

Pachydiplax longipennis (Burm.). 9 (r). One dead nymph collected 14 days after treatment.

Mesothemis simplicicollis (Say). 8 (c), 9 (f). Not reduced in either of the ponds.

HEMIPTERA

Mesovelia mulsanti bisignata Uhl. 2 (c), 7 (c). Exterminated on both ponds.

Hydrometra martini Kirk. 2 (r), 3 (r), 4 (f), 6 (a), 8 (a). Exterminated on all ponds.

Gerris marginatus Say. 2 (c), 3 (f), 4 (r), 6 (f), 8 (c), 9 (c). Exterminated on all ponds.

Gerris remigis Say. 4 (r). Not found after treatment.

Microvelia hinei Drake. 3 (f), 4 (f), 7 (r), 8 (r). Exterminated on ponds 3, 4, and 7. One specimen taken on pond 8 the day after treatment.

Notonecta undulata Say. 2 (c), 4 (c), 5 (a), 6 (c), 7 (a), 8 (c), 9 (c). Exterminated in all ponds. Recently hatched nymphs were present in pond 8, 14 days after treatment.

Buenoa. 2 (r). Not found after treatment.

Pelocoris femoratus (P.deB.) 6 (r), 8 (c). In pond 6 one dead specimen found 8 days after treatment; in pond 8 not reduced at all.

Ranatra fusca P.deB. 7 (r). Not found after treatment.

Lethocerus americanus (Leidy). 5 (r), 6 (f). In pond 5 one live specimen taken 5 days after treatment. In pond 6 two dying specimens 5 days after treatment and one dead specimen 8 days after.

Belostoma flumineum Say. 3 (r), 8 (r). One live specimen in pond 3, 8 days after treatment and one in pond 8, 1 day after.

Arctocorixa interrupta (Say). 4 (c), 5 (f), 7 (r), 8 (c). Probably exterminated in all ponds.

Sigara spp. 4 (c), 5 (r). Probably exterminated in both ponds.

Megamelus davisi V. D. 2 (a), 8 (a). Exterminated on both ponds. A few specimens were back on pond 2, 8 days after treatment.

MEGALOPTERA

Chauliodes. 8 (r). One specimen found dead the day after treat-

ment. In a preliminary experiment a shallow swampy area near Bowie, Md., was sprayed early in March. Within an hour large numbers of this form were coming out of the mud and dying.

Sialis. 1 (r). Not collected after the treatment.

COLEOPTERA

Haliplus sp. 8 (r). One specimen taken the day after treatment.

Hydrocanthus sp. 8 (r). Adults probably exterminated.

Hydroporus sp. 6 (r). Adults probably exterminated.

Ilybius. 8 (c) Adults probably exterminated.

Matus sp. 8 (r). Adults probably exterminated.

Acilius fraternus (Harr.). 9 (c). Adults exterminated.

Graphoderes liberus (Say). 4 (r), 8 (c). Adults exterminated.

Dineutes. 2 (a), 4 (a), 5 (a), 6 (f), 8 (c), 9 (c). Adults exterminated on all ponds.

Gyrinus. 2 (c), 4 (f), 6 (f), 7 (c), 8 (r). Adults exterminated on all ponds.

Berosus. 1 (r), 3 (r). Adults probably exterminated.

Hydrous triangularis (Say). 3 (r), 6 (f), 7 (r). Adults probably exterminated.

Tropisternus spp. 4 (f), 5 (f), 6 (f), 7 (r), 8 (c), 9 (c). Adults probably exterminated.

Enochrus. 8 (f). Adults probably exterminated.

Helodidae (larvae). 6 (r), 7 (r), 8 (f). One dead at the edge of pond 6 a few hours after treatment, one dead at pond 7, 8 days after, several dead at pond 8 the day after treatment, and one alive at the same pond 4 days after treatment.

Donacia (larvae). 2 (r), 3 (f). Not affected in either pond.

TRICHOPTERA

Polycentropus. 3 (r). Not collected after treatment.

Ptilostomis. 1 (r), 6 (r). Not collected after the treatment.

DIPTERA

Dasyhelea. 1 (r). Not collected after the treatment.

Sphaeromias? sp. 1 (a), 2 (c), 3 (a), 4 (r), 5 (c), 6 (f), 7 (f). Not affected by the treatments in any of the ponds.

Bezzia? sp. 1 (f), 2 (f), 3 (f), 6 (f). Numbers not reduced in any of the ponds.

Chaoborus. 5 (r), 7 (r), 8 (a), 9 (a). In pond 5 one dead specimen taken 8 days after treatment, in pond 7 one before and none after treatment. In pond 8, the day after treatment, thousands of half-grown larvae were dead and dying. Full-grown larvae and the one pupa seen were still unaffected. Five days after treatment all found were dead except for a few dying. In pond 9 thousands of dead larvae were found 5 days after treatment, none alive.

Pentaneura. 1 (a), 2 (c), 3 (c), 4 (r), 5 (f), 7 (f), 8 (r). There seemed to be no change in numbers in ponds 1, 2, and 5. The species was not found again in pond 4 after treatment, and in pond 7 the only specimens collected were five dead ones 5 days after treatment. The only collection in pond 8 was one live specimen the day after treatment.

Procladius culiciformis (L.)? 1 (a), 2 (c), 3 (a), 4 (a), 5 (r), 6 (f). The numbers of this species remained approximately unchanged.

Clinotanypus caliginosus (Joh.)? 1 (f), 3 (c), 4 (r), 5 (r). No reduction in numbers in any of the ponds.

Polypedilum sp. 1 (a), 2 (f), 3 (a), 4 (c), 5 (a), 6 (c), 7 (c). There seemed to be no reduction in any of the ponds.

Glyptotendipes paripes (Edw.). 2 (c), 4 (r), 5 (r), 7 (r). Specimens were found in ponds 2 and 4, 8 days after treatment, but not in ponds 5 or 7.

Glyptotendipes lobiferus (Say). 1 (r), 7 (c). Not collected in pond 1 after treatment. In pond 7 the number was apparently unchanged.

Tendipes (Limnochironomus) sp. 9 (r). One collected 5 days after treatment, none later.

Tendipes decorus (Joh.)? 9 (r). One collected 5 days after treatment, none later.

Tendipes tentans (F.)? 2 (r), 3 (r), 7 (f). Collected after treatment only in pond 2.

Cryptochironomus. 4 (r). One collected 8 days after treatment.

Harnischia. 2 (r), 4 (c), 5 (c). Apparently not reduced in any of the ponds.

Micropsectra? 1 (r), 2 (r), 3 (r). Collected after treatment only in pond 2.

Chrysops. 1 (c), 2 (f), 3 (c), 5 (r), 6 (c), 7 (c), 9 (r). Not collected in pond 5 after the treatment. Collections in the other ponds show no reduction in numbers.

Empididae (larva). 1 (r), 3 (c), 6 (r), 7 (r). The single specimen collected 8 days after treatment in pond 7 was a dead one. Otherwise there was no evidence of adverse effects of DDT.

ACARINA

? Oribatella aquatica Bks. 1 (a), 2 (a). All dead the day after treatment.

Hydrachna sp. 6 (r). One collected 8 days after treatment.

Diplodontus despiciens (Müll.). 3 (f), 6 (f), 8 (a). Not affected. There was an increase after treatment.

Arrhenurus. 8 (a). Not affected. There was an increase after treatment.

ARANEIDA

Dolomedes sexpunctatus Hz. 1 (f), 3 (r), 8 (c). No careful observations were made, but this species seemed to be greatly reduced.

Generalizations

Various aquatic species show great differences in susceptibility to DDT. The Planaria, Oligochaeta, Entomostraca, Hydracarina, and Mollusca that we encountered seemed totally immune to the dosages used. Most Ephemerida, smaller Plecoptera, adults of Elmidae, most Trichoptera, Simuliidae, and many Tendipedidae (= Chironomidae) were very susceptible. Nymphs of larger dragonflies, Pteronarcys (Plecoptera), Nigronia (Megaloptera), some Heleidae (Diptera), and Chrysops seemed little if at all affected. For some groups variation in susceptibility is explainable by differences in opportunity to contact the poison. Insects living on the surface of the water or coming to the surface to breathe were extremely susceptible to an oil solution of DDT, and those living in the bottoms of ponds and streams relatively immune. In swift streams are many species securing all or much of their food by straining it from the water. This habit probably accounts for the susceptibility of Isonychia (Ephemerida), many Trichoptera, Simuliidae, and some Tendipedidae.

On ponds a 12-percent solution of DDT in oil at the rate of 1 gallon per acre (1 lb. of DDT), or of five times that amount of the solvent and carrier alone, exterminated practically all the surface insects and those breathing at the surface. Casual observations suggest that these forms are similarly affected on streams sprayed with DDT. Most free-swimming or crawling insects in ponds were severely reduced in numbers by the lowest dosage and some were exterminated. Insects in the bottoms of ponds were relatively safe at the dosages used.

A deposit of a DDT-oil solution on Ash Creek at the rate of about 0.25 pound per acre killed about 90 percent of the total insect population and apparently exterminated about one-third of the species studied. In the ravine brook an estimated deposit of 0.8 pound of DDT per acre killed about 85 percent of the insect population, leaving only the resistant species and a few scattered survivors of those moderately resistant. Much of the survival in the ravine brook was of species protected in leaf drifts. In Bowback Creek a deposit of perhaps 0.25 pound per acre on a 0.2-mile stretch had no observable effect at 0.25 mile below. Results in the ravine brook also indicate that streams carry lethal amounts of DDT for only a short distance. Our experiments lead us to believe that, when a stream and its watershed are sprayed by airplane, most if not practically all damage to the stream's fauna is by DDT deposited on its surface, not by DDT washed or leached into the stream.

The rate of repopulation of a pond or stream depends upon how soon the DDT disappears from the water and the length of life cycle, number of survivors, and possibilities for migration of the species involved. In a pond the DDT may remain in lethal amounts for days or weeks, depending on dosage, drainage, and other factors. In a stream most of it is probably carried off in a day. Many pond species have several generations a season, and it is believed that as a group they have a greater tendency to migrate than do stream species. Hence a small pond should, and according to our observations does, regain most of its fauna a few weeks after the DDT is no longer effective. Most stream species take a year for a generation, and many of the larger predators several years, with the result that repopulation is slow. The ravine brook treated in late May showed no repopulation by late August. Bowback Creek, with a short part of its course treated in early June, seemed to show a little recovery in late August.

The present studies show the approximate effect of DDT on aquatic invertebrates in certain kinds of ponds and streams. There is a great need, however, for more exact information derived from studies on different formulations and dosages used on aquatic habitats. A cardinal need for further experimental work is better control of the airplane application and more knowledge of the distribution of DDT in the habitat.

Fig. 1--The stream square-foot sampler in use. The scrim collecting bag trails downstream from the sampler.

Table 1.--Number of invertebrates per square foot in the ravine brook bottom samples.

Forms	Upper station									Middle station								Lower station								Effect of treatment 2/
	Pretreatment				Posttreatment					Pretreatment			Posttreatment					Pretreatment			Posttreatment					
	May 5		May 17		June 6		June 29			May 5		May 17	June 6		June 29			May 5		May 17	June 6		June 29			
	(1) 1/	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(3)	(1)	(2)	(1)	(1)	(2)	(1)	(2)	(3)	(1)	(2)	(1)	(1)	(2)	(1)	(2)	(3)	
PLATYHELMINTHES																										
Planaria	1				1			1	1									1						3		A
ANNELIDA																										
Lumbriculidae		2		1		2	1			4			4		3		1							1		A
Tubificidae?	1			1				2		1	1				3	1				1				1	4	A
CRUSTACEA																										
Cambarus b. bartonii (F.)	1	1		1							1							1			2				1	B
EPHEMERIDA																										
Iron nr. pleuralis																		35	27	47						C
Ameletus sp.		1	3	12						4	1	12						3	4	2						C
Paraleptophlebia moerens McD.				6														1				1	1	1	1	
Habrophlebiodes	2	3		2						2	4	2														C
Baetis nr. parvus				2						1	2	8						6	1	1						C
ODONATA																										
Cordulegaster													2				2									A
PLECOPTERA																										
Peltoperla arcuata Ndm.		7		1								1								2		1				B
Nemoura		10	1	4					1		1	4						17	7		6	9		2		B
Leuctra	1	2	1	4								1						35		2	1	14	2			E
Alloperla	1	1	2	4								3												2		D
Diploperla hastata (Bks.)	1	2	2	1							3										3			2	2	E
Isoperla bilineata (Say)			2	1								2						2	4	4	2	9	2	2	3	E
TRICHOPTERA																										
Rhyacophila sp. B												2							2							B
Dolophilus moestus (Bks.)	3	2									1		2						8	2						D
Pycnopsyche				1							4			1				1				1				B
Neophylax																						4		2		
Lepidostomatidae			1	1	1					1	1							16	1	3		3	1	1		B
DIPTERA																										
Hexatoma spinosa	1										2							2								B?
Prosimulium hirtipes (Fries)	2	1									1	3						1	22	1						C?
Pentaneura			1															2		1	1					
Hydrobaeninae sp. C	2	2								1		4						1								
Hydrobaeninae sp. F	1	1																2								
Hydrobaeninae spp.		1	3	1							1							2	1	1	1	1	1			B
Polypedilum	2			2							1							3								
Calopsectrini	11	4	1	6						9	5	5						11	5	1						C
Chrysops						1					2															A?
OTHER INVERTEBRATES	5	4	3			1	2	1		2	3		2		1	1		2	1	1	1		2	1		
Totals	35	44	20	51	2	4	3	4	2	25	34	47	10	1	7	2	3	144	83	69	17	43	9	18	11	
Percent reduction								92								87								80		

1/Numbers in parentheses refer to different square-foot samples taken on the same date.

2/A, not affected; B, reduced; C, exterminated; D nearly exterminated; E, exterminated except at lower station.

Table 2.--Number of invertebrates per square foot in Ash Creek and Silver Creek bottom samples.

Forms	Upper station				Middle station				Lower station				Silver Creek	Effect of treatment[2]
	Pretreatment		Posttreatment		Pretreatment		Posttreatment		Pretreatment		Posttreatment			
	July 14		Aug. 23		July 14		Aug. 23		July 14		Aug. 23		Aug. 23	
	(1)[1]	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	
PLATYHELMINTHES														
Planaria			1	2	2		16	21		1		1	2	A
ANNELIDA														
Oligochaeta		1		1	2	1	2	2	1		5	1	5	A
CRUSTACEA														
Malacostraca		1			2	2								
EPHEMERIDA														
Hexagenia	5	1				1								C
Stenonema ithaca (C.&L.)									4	5				C?
Stenonema pudicum (Hag.)		4		1	7	5			6	5				E
Heptagenia aphrodite McD.									2	6				C?
Heptagenia julia Traver									3	2				C?
Iron vitreus (Wlk.)									2	6				C?
Isonychia thalia Traver	6	19			64	148			27	2				C
Paralaptophlebia guttata McD.					7	9			4	1				C
Paraleptophlebia mollis Eat.					1	33			15	19				C
Habrophlebia vibrans Ndm.?		1	2								1	3	2	
Ephemerella cornutella McD.		1							3	7				C?
Ephemerella deficiens Morg.					26	39			18	2				C
Ephemerella rotunda Morg.			13	6		9	5	6	2	2	23	50	3	A?
Ephemerella invaria (Wlk.)	7	1	2	1	3								5	A?
Baetis spp.	24	16			40	12			29	2			4	C
Pseudocloeon dubium (Walsh)									9	22				C
Pseudocloeon punctiventris (McD.)	3	1							46	1			3	C
Other Ephemerida		3		1	4	1	1		9	16		1		
ODONATA														
Lanthus					4	1	2	1	1			1	11	A
Boyeria			1						2					A
Other Odonata		1	3											A
PLECOPTERA														
Pteronarcys biloba Newm.	1			1	1	3	1	2	8					A
Peltoperla arcuata Ndm.	10	12		13	262	112	6	19					27	B
Leuctra	9	9	2		45	117		5	27	24	4	5	16	B
Isoperla holochlore (Klap.)		1			17	14			5				8	C
Neophasganophora capiteta (Pict.)		1	1	1	7				3	9				B
Other Plecoptera	1	1			1		1	6	2				12	
MEGALOPTERA														
Nigronia serricornis (Say)	1	1		1	1	4			4	2			7	B
Sialis			1		2	2			1					
COLEOPTERA														
Stenelmis crenata (Say)					1	1								
Heterlimnius tardellus (Fall) (adult)	49	34		3	36	8			80	1	1		122	B
Heterlimnius tardellus (Fall) (larva)	5	2	3	12	12	7	16	6	15		1		59	A
Heterlimnius ovalis (Lec.)? (larva)			3	2		3	1	1	1					A
Other Coleoptera	1					1					1	1		
TRICHOPTERA														
Rhyacophila fuscula (Wlk.)					4								6	
Rhyacophila sp. B					10	4	3		7	4	1	3	4	B
Glossosoma		2	9											
Trentonius distinctus (Wlk.)		2			34	11				10	2		24	D
Psychomyiidae						2	1	1					4	
Hydropsyche simulens Ross	1	3							2			1	2	B
Hydropsyche sp. A		1			5				6	6			10	C
Psilotreta	6	3												C?
Lepidostomatidae	1				6	28								C?
Micrasema	4	1	3	37	1		1	2	25				43	A
Other Trichoptera		1	1	2	1	1	5	2					6	
DIPTERA														
Hexetoma spinosa (O.S.)		1			2	1	1	2	2				1	A
Simuliidae		2			3				2				2	C?
Heleidae sp. A		1	4	1	4	23	1	4	2			1	7	A?
Pentaneura	11	5	1		8	38			18	7		2	2	B
Cricotopus		1			2	1			1					C?
Hydrobaeninae sp. F		2			12	44	1		2	1			1	D
Hydrobaeninae spp.	4	5	5	3	10	12		1	7	5	2	2	11	
Microtendipes		1				1			3	1				C
Polypedilum	6	7	1		38	178	1		3			2	10	D
Calopsectrini	5	6	2		9	24			6	7		1	66	D
Chrysops	1		1	1										A
Other Diptera	1	3	3		2	1			2	2		3	4	
HYDRACARINA														
Hygrobates	34	1	7	21			3	2			1			A
Other Hydracarina			2	4		1	1	2			7	1	1	A
MOLLUSCA			1					1	1	5		2		A
Totals	196	159	72	114	698	903	69	86	418	183	49	81	490	
Percent reduction, incl. E. rotunda			48				90				78			
Percent reduction, excl. E. rotunda			53				91				90			

[1] Numbers in parentheses refer to different square-foot samples taken on the same date.
[2] A, not effected; B, reduced; C, exterminated; D, nearly exterminated; E, exterminated except at upper station.

Table 3.--Number of invertebrates per square foot in Bowback Creek and Rattlesnake Creek bottom samples.

Forms	Upper station								Middle station							
	Pretreatment				Posttreatment				Pretreatment				Posttreatment			
	May 4		June 7		June 28		July 25		May 3		June 7		June 28		July 25	
	(1)[1]	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
ANNELIDA																
Tubificidae			1								2				2	
CRUSTACEA																
Cambarus b. bartonii (F.)	1						1		1		1	1				
EPHEMERIDA																
Stenonema nr. pulchellum (Walsh)			1								1	1				
Habrophlebiodes	3		6	6	4			4	6	3	12	5	1			
Baetis flavistriga McD.	7	2	2	5					1	6	3	2				
Baetis spp.	1	1	24	7				3				1				
Pseudocloeon carolina Bks.		1	1						1	2	3	1				
Other Ephemerida	24	31	6	9	8		48	2	9	4	4	5	1	4	1	
ODONATA																
Lanthus																
Boyeria				1			1									
PLECOPTERA																
Pteronarcys biloba Newm.			4	2	2		11					1	1			
Nemoura	2	16	6	2					2			2				
Leuctra	7	7	1	6	3		2	1			1				3	
Acroneuria carolinensis (Bks.)	5	6	6	5	5	2		1	7	7	6	6	1	1	1	1
Other Plecoptera	2	4	3		1		2	2	5	6	4				2	
MEGALOPTERA																
Nigronia serricornis (Say)	5	1	1	13	1	5	2	4		3			1			2
TRICHOPTERA																
Trentonius distinctus (Wlk.)			6	4							2	39				
Psychomyiidae	1		2	1	1				1	1						
Diplectrona modesta Bks.	1	3		1					4	1		2				
Hydropsyche sp. A	2	1	1						2							
Neophylax	6	2		1	1	2	2		5	6				2		
Lepidostomatidae			2	2							3	1				
Other Trichoptera		7	1				5	1	2	4		4	1		1	
DIPTERA																
Hexatoma spinosa (O.S.)	4	1		4	5	1	1	2	3	8	2	1	1	3	1	1
Simuliidae	1	6	1						6			6				
Heleidae sp. A	4		2	1	5	2						2				
Pentaneura	10	5	1	9					1	3	9	2		1		
Cricotopus	4	4	11	20	12								3			
Microtendipes	1		19	6	5	2	1			4	4					
Polypedilum	54	59	2	1			2	1	11	8	1	4				
Other Tendipedidae	135	70	28	35	1		10	3	16	22	13	21	1	1		2
Other Diptera	5	6	1	3	3			1	2	1	4	2				
OTHER INVERTEBRATES			3	4	2	1	12	1			1	2	1			
Totals (excluding Cricotopus)	281	229	131	128	47	15	100	26	85	89	76	111	9	12	11	6
Percent reduction from June 7					76		51						89		91	
Percent reduction due to DDT					65		13						84		84	

[1] Numbers in parentheses refer to different square-foot samples taken on the same date.

[2] A, not affected; B, reduced; C, exterminated.

Lower station								Bowback Creek check								Rattlesnake Creek check								Effect of treatment[27]
Pretreatment				Posttreatment				Pretreatment				Posttreatment				Pretreatment				Posttreatment				
May 3		June 7		June 28		July 25		May 4		June 6		June 28		July 25		May 4		June 7		June 28		July 25		
(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	
		1	2		1			2	2			3	1	2										A
		2																						C?
			3														1		2					C?
		10	4		3		1								5							1	1	B?
3	4	5	16							53	110	27	6	7	3			1	1	1	2	9	1	C
			2					10	6	7	2	45	43			1	8			5	4	4	6	C
2	1		3	1				17	7	3	2	2	2	1		1	7				1	1	3	B
9	6	1	1	1	5			61	46	22	39	24	8	4		48	199	35	20	14	24	6		
							1							1										A
																	1							A
				1				1						1			1					2		A?
1	1							5	2	2		1												B
			1					1	1					2		1				1				
2	2	7	9	3		1						1				3	5				2			B
8	8	3		1			2	3				1			1		3	8	3	6	2	4	4	
2	2	1				1	1									5	9	1	1	1	10	1		A?
			5														1	8						C
		3	2																1	1	2		1	B
5	1	5	2																					C?
			2				1	3		1						4	24	21	10	2	9	3	1	B
4	1							1			1					13	4	1	5	2				B?
		2						2	2	1	1													B
1	3		3							1		13	5		1	7	4	3		3			2	
1		1		2			1								1	2	2	3		1	1	1	1	A
			1					5	1													2		C?
2		4						1			2						2							B
1	2	1	4					9	3	11	16	1	1				3	1						B
2			3	23	8						2	4	3					1			1			
	2		1											1		2	4	1						C?
17	7							11	4	1						1	3	1	5			2		C?
38	17	6	15	1		5	3	103	63	5	6	5	11		2	4	12	4	2	1		19	8	
1		1	1					2	2							8	3	4	8		5			
	1		1						1		1						1	1			2	2		
97	58	53	78	10	9	7	10	237	140	107	180	123	77	19	13	100	297	93	58	38	64	57	28	
				85		87						30		89						32		44		
				78		77																		

Table 4.--Description and treatment of the ponds used for DDT studies

Pond No.	Size	Average depth	Aquatic vegetation	Spray formula (quantity per gallon)	Dosage of DDT
		Inches			Pounds per acre
1	20 x 50 ft.	3	Abundant	Xylene 1 qt. + fuel oil 3 qt.	5
2	do.	21	Moderate	do.	5
3	do.	5	Abundant	DDT 1 lb. + xylene 1 qt. + fuel oil 2.65 qt.	1
4	do.	25	Sparse	do.	1
5	do.	20	Sparse	do.	3
6	do.	11	Abundant	do.	5
7	do.	20	Moderate	do.	5
8	0.3 acre	40	Abundant	do.	1
9	0.2 acre	60	Moderate	DDT 1 lb. + xylene 1 qt. + Igepal 20 ml. + water 2.64 qt.	5